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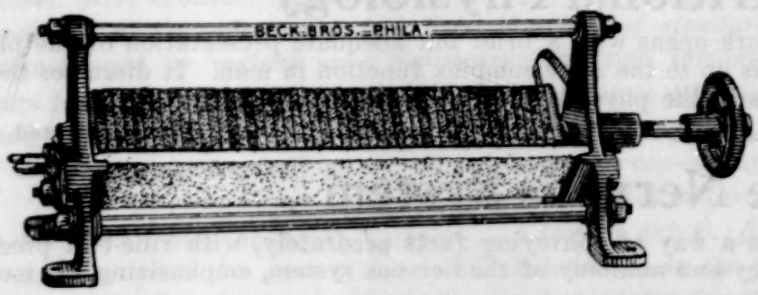

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SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. McKeen Cattell and published every Friday by

THE SCIENCE PRESS

Lancaster, Pa. Garrison, N. Y.

New York City: Grand Central Terminal.

Annual Subscription, $6.00. Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

Entered as second-class matter July 18, 1923, at the Post Office at Lancaster, Pa., under the Act of March 3, 1879.

ABSOLUTE MEASUREMENTS OF SOUND[1]

IT is now more than thirty years since it occurred to me to devise an instrument that should be capable of measuring the intensity or loudness of any sound at any point in space, should be self-contained and portable, and should give its indications in absolute measure. By this is meant that the units should be such as do not depend on time, place, or the instrument, so that, though the instrument be destroyed and the observer dead, if his writings were preserved another instrument could be constructed from the specifications and the same sound reproduced a hundred or a thousand years later. The difficulty comes from the fact that the forces and amounts of energy involved in connection even with very loud sounds are extremely small, as may be gathered from the statement that it would take approximately ten million cornets playing *fortissimo* to emit one horse-power of sound.

Before we can measure anything we must have a constant standard. In sound we must construct a standard which emits a sound of the simplest possible character, which we call a pure tone; it will be like that emitted under proper conditions by a tuning-fork, which is described by saying that the graph representing the change of pressure with the time shall be that simple curve known as the sinusoid or curve of sines. From this connection we say that the pressure is a harmonic function of the time. Unfortunately the pressure change is so small that at no point in a room, even when a person is speaking in a loud tone, does the pressure vary from the atmospheric pressure by more than a few millionths of an atmosphere. Thus we require a manometer millions of times as sensitive as an ordinary barometer, and, in addition, since the rhythmic changes occur, not once in an hour or day, but hundreds of times per second, if we wish the gauge to follow the rapid changes accurately, we have many mechanical difficulties.

The problem of a standard of emission has been solved by a number of persons, including Professor Ernst Mach and Professor Ludwig Boltzmann, and Dr. A. Zernov, of Petrograd, a pupil of the celebrated Peter Lebedeff. The problem of an absolute instrument for the reception and measurement of a pure

[1] An address before the Royal Institution of Great Britain, June 10, 1921, by the late Arthur Gordon Webster, D.Sc., LL.D., Hon.M.R.I., Professor of Physics, Clark University.

tone has been also successfully dealt with by a number of investigators, among whom may be mentioned Professor Max Wien, of wireless fame, the late Lord Rayleigh, and Lebedeff. But there remains a third step in the process, which is as important as the first and second. Given the invention of the proper standard source of sound, which I have named the "phone," because it is *vox et praeterea nihil,* and of a proper measuring instrument, which should evidently be called a phonometer, there still remains the question of the distribution of the sound in space between the phone and the phonometer. Any measurements made in an enclosed space will be influenced by reflections from the walls, and, even if we had a room of perfectly simple geometrical form, say cubical, and were able to make the instruments of emission and reception work automatically without the disturbing presence of an observer, it would still be impossible to specify the reflecting power of the walls without a great amount of experimentation and complicated theory. Nevertheless, this is exactly what was done by the late Professor Wallace C. Sabine, of Harvard University, who employed the human ear as the receiving instrument. Those who have made experiments upon the sensitiveness of the human ear for a standard sound will immediately doubt the possibility of making precise measurements by the same ear at different times, and particularly of comparing measurements made by one ear with those made by another. Nevertheless, Sabine attained wonderful success, and was able to impart his method to pupils who carried on his work successfully, so that he was able to create the science of architectural acoustics and to introduce a new profession. Still, the skill that required three or four months to attain by Sabine's method may be replaced by a few minutes' work with the phonometer.

In order to avoid the influence of disturbing objects, the observer should take the phonometer to an infinite distance, which is manifestly impossible. The method employed was to get rid of all objects, except a reflecting plane covered with a surface the coefficient of reflection of which could be measured. For this purpose the teeing ground of a suitable golf course was used. With the present instrument it can be determined in a few minutes, if there is no wind.

In 1890 I proposed to use a diaphragm made of paper, which should be placed, shielded on one side, at the point where the sound was to be measured. In order that the effect of the sound should not be distorted, the membrane, instead of having to do any work, as in the case of the diaphragm of the phonograph in digging up the wax, or in that of the microphone in compressing the carbon, was to be perfectly free, but was to carry a small plane mirror cemented on at its center. In close juxtaposition and parallel with this was the plane side of a lens which, viewed in the light from a sodium flame, was to give Newton's rings or interference fringes. Of course, when the sound falls upon the diaphragm the fringes vibrate rapidly and disappear from sight.

By the introduction of a Michelson optical interferometer, two of the difficulties of this instrument were overcome—namely, (1) that of adjusting the lens so that it would not strike the vibrating mirror, since the mirrors in the interferometer could be as far apart as one pleased; and (2), more important still, it permitted the use of fringes in white light, so that it was possible to use gas, incandescent, or arc light with excellent effect. A further improvement was introduced by the use of a thin plate of mica for the diaphragm.

To obtain the sensitiveness necessary to measure sounds of ordinary intensity, the property of resonance is employed twice—*i.e.,* a system of two degrees of freedom is used. First, the plate resounds to a sound more strongly as it is tuned more nearly to it; and second, a resonator that can also be tuned is put behind the plate. The sound entering by the hole in the resonator is magnified by the tuning, and acts upon the plate, which is also tuned. A graph can be plotted in which one coordinate represents the stiffness of the plate, or rather what may be called the mistuning, which is the stiffness lessened by the product of the mass by the square of the frequency. The other coordinate represents the corresponding quantity for the resonator, the stiffness of which depends simply on the volume into which the air is compressed, while the effective mass depends on the dimensions of the whole, and its damping on the sound radiated from the mouth. It is then found that the tuning should not be such as to make the representative point occur at the middle of the figure, making both mistunings zero, but that both mistunings should be of the same sign and a certain magnitude, depending on the coefficients of damping of the two degrees of freedom of the coupled system. The mathematical theory is precisely that of a wireless receiver. The ultimate sensitiveness depends on the smallness of the damping of the plate.

The apparatus as it was built several years ago was mounted upon a heavy bronze stand, covered at the back by a heavy bronze cover to keep out the sound, while the three shafts turning the screws of the interferometer adjustment protruded through sound-tight fittings. Upon the front of the instrument a properly tuned resonator was attached, and at the side was a small incandescent lamp with a straight, horizontal filament, an image of which was projected by a lens upon the first mirror of the interferometer. Upon this was focused a telescope, giving in the reticule an image of the horizontal, straight filament, crossed by

the vertical interference fringes seen with white light. In order to get these the plate must be in the proper position within a few hundred-thousandths of an inch. The objective of the tuning-fork was carried by a tuning-fork which oscillated vertically, tuned to the pitch of the pure tone to be examined, and this, combined with the horizontal motion of the fringes, resulted in a figure of colored fringes in the form of an ellipse. On slightly mistuning the fork, the ellipse could be made to go through all its phases, and when it was reduced to an inclined straight line its inclination was read off on a tangent scale. The amplitude of the compression of the air in the sound was then directly proportional to the scale-reading.

While the interferometer is still used for calibration, the movement of the diaphragm is recorded for actual measurements by a thin steel torsion strip carrying a concave mirror. A lamp with a vertical, straight filament is viewed through a telescope into which the small mirror focuses the image of the filament on the reticule, and a magnification of from 1,200 to 1,500 is used, so that the sensitiveness is about the same as with the interferometer.

At first the only method of tuning was the clumsy one of changing the mass of the diaphragm by adding small pieces of wax. This was not capable of continuous variation. Now the diaphragm has been discarded and replaced by a rigid disc supported by three steel wires in tension. The disc is made of mica or aluminium, and is carried by a little steel spider containing three clamps to hold the wire. The tension is regulated by three steel pegs, one of which is controlled by a micrometer screw. The disc is placed in the circular hole through which the sound enters the resonator. This has the advantage of reducing damping very largely, and thus of increasing the sensitiveness enormously. The instrument now competes with the human ear, and can be tuned over two octaves or more.

This sensitiveness can be demonstrated by projecting the colored interference fringes on a screen and singing faintly in a remote part of the room, when the fringes will disappear. Using the telescope end of the apparatus, the instrument will indicate the sound of a tuning-fork when one can scarcely hear it. It is obvious that the disc may be made the diaphragm of a telephone and thus increase its sensitiveness. In fact, Professor King has used such a telephone to record wireless messages with great success. He has also invented another sort of tunable diaphragm composed of a stretched steel membrane with compressed air behind it, which enables it to be tuned continuously, but over a smaller range.

I now come to the source of sound—the phone. This has been reduced to a reversed form of the phonometer. The disc is driven by an interrupted or alternating current by means of electromagnets, and tuned like the phonometer. Its excursion is measured by a powerful microscope, and the emission of sound is known in absolute measure. It is now driven by a triode valve tube, in the manner suggested by Professor W. H. Eccles, of Finsbury Technical College, London, for a tuning-fork. This has been worked out for me by Dr. Eckhardt at the Bureau of Standards in Washington.

The third part of the investigation involves a determination of the coefficient of reflection of the ground. The phone is set at a convenient height, and the phonometer at a convenient distance. Either is then moved along at a constant height and the varying deflections of the phonometer are read while the sound remains the same. Interference sets in between the direct sound and its image reflected in the ground, and the existence of a minimum is obvious to the most naïve observer by the ear alone. The reflection of either grass or gravel was found to be about 95 per cent., while, with a most carefully deadened room, the walls of which were covered with thick felt, there was perhaps 20 per cent. reflection. The whole measurement at both ends and the transmission checks up with an accuracy of about 2 per cent.

With this apparatus all sorts of acoustical experiments may be performed. By attaching to the phonometer a long glass tube or antenna, it has been possible to explore all sorts of places, such as the field within a horn or tube lined with an absorbent substance. The transmission of sound through fabrics, walls and telephone booths may also be quickly examined. The instrument is used by psychologists and by telephone and acoustic engineers, and is of interest to navigators. An interesting by-product is an instrument for showing the direction of an acoustic signal in the fog. It has been called a phonotrope, on the analogy of heliotrope, which turns to the sun. It consists of two equal horns which bring the sound to the opposite sides of the disc. When the whistle blows, the band of light spreads out, and on turning the instrument it closes to zero when the sound is directly ahead. Thus at several miles the direction is given to within two or three degrees.

Finally, let us consider that mystery of sound, the violin, which has been studied by Professor Barton, of Nottingham, and Professor Raman, at Calcutta. This may be described by the engineer as a box of curious shape, made of a curious substance, wood, of variable thickness, with two holes of strange figure to let the sound out of the resonating box. The latter is actuated by a curious substance, catgut, made of the intestines of a sheep, and set in vibration by another curious substance, the tail of a horse. Yet from this wonderful box we get the most ravishing sounds, which affect profoundly the emotions of the most

civilized. Yet the physicist reduces all musical instruments to combinations of resonators with strings, membranes, bars, plates and horns. The mathematical theory of strings was given by Euler two hundred years ago, of bars and plates less than a hundred years, of resonators by Helmholtz and Rayleigh, and I have recently added a theory of horns which, while only approximate, works well in practice, and investigations are now being carried out by such methods on vowels and the violin.

ARTHUR GORDON WEBSTER

SCIENCE AND PHILOSOPHY IN VIRGIL

RELIGIOUS superstition once borrowed such a large portion from the works of Virgil, though it was accomplished in a way as inexplicable as it was unwarranted, that we are apt, from the standpoint of science, to dismiss him altogether as a source from which to gather anything useful in the history of scientific thought. It is no wonder, however, that the ardent early fathers of the Christian church found in the fourth Ecologue an indication, pregnant with prophecy, conscious or unconscious on the part of the poet, of the coming of Christ and the regeneration of the world, a return to its golden age. Other interpretations have of course been made of the lines, but the ready credulity of a budding faith had every temptation to accede to the conviction that Virgil was a herald of the approaching light of the world. But the reputation Virgil had in the Middle Ages partook of that of a man of science. He was a wizard, the happy man who knew the causes of things,

> Felix qui potuit rerum cognoscere causas.[1]
> How blest the sage! whose soul can pierce each cause
> Of changeful Nature, and her wondrous laws.

As a matter of fact this was no boast of Virgil, it was only his sigh that he did not understand them all and it is difficult to see, in spite of Comparetti's monumental work,[2] what could have given the mind of the middle ages that respect for Virgil as a man of science, of which we find so many traces in the authors of the pre-Renaissance. For them he was not so much the necromancer of verse, recognized by a later and an earlier age, as a wizard of knowledge in natural science. The lines however which precede the one above, so often quoted, give us a glimpse of the kind of things he had in mind when he longed for a knowledge of their causes.

> The muses [he declares] . . . will show me the paths of heaven and the stars, the various eclipses of the sun and the changes of the moon, whence comes the quaking in the earth, by what force the sea swells high on the rocky shores and again sinks back upon itself, why the winter sun rushes on to plunge beneath the ocean wave, what it is lengthens out the tedious nights, but if I could not draw nigh to these parts of Nature the cold blood would gather round my heart.

That is, as I take it, for Sotheby certainly goes astray here, if he could not imagine some rational explanation of these things he would stand terror stricken in the presence of God. That is the reason, it seems to me, he exclaims, "fortunate indeed is he who perceives the causes of things."

In Virgil, as in all ancient writers, we get a far franker acceptation than we do to-day, a much plainer indication of the all pervading pantheism in the fundamental beliefs of men. It is probably as widespread to-day, but it is hidden beneath a reticence which the mystic faith of Christ, quite in contrast to the ancient pagan tendencies, imposes on its communicants. Still it peeps out now and then, not in science alone where it has the support of physics, but in religious pedagogy with the maxim that God is everywhere. The haruspices and the augurs thought or, in Virgil's day, pretended to think that the birds bore the impress of the will of the gods on their in-

[1] Georgicon II. 490. I use Sotheby's translation here, but the classics are immortal because they have a message for each generation, otherwise they would have perished. Only from the text can the modern critic judge if the references from it are valid for the scientific thought of this generation. There can be no doubt Virgil is here referring to Lucretius whose De Rerum Natura was his model in youth.

[2] Virgilio Nel Medio Evo, per Domenico Comparetti, Fierenze, 1896.

[3] Me vero primum dulces ante omnia Musae,
quarum sacra fero ingenti percussus amore,
accipiant caelique vias et sidera monstrent,
defectus solis varios lunaeque labores;
unde tremor terris, qua vi maria alta tumescant
obicibus ruptis rursusque in se ipsa residant,
quid tantum Oceano properent se tinguere soles
hiberni, vel quae tardis mora noctibus obstet,
sin has ne possim naturae accedere partis
frigidus obstiterit circum praecordia sanguis:

But, most beloved, ye Muses! at whose fane
Tranced by deep zeal I consecrate my strain,
Me first accept! and to my search unfold
Heaven and her host in beautious order roll'd;
Th' eclipse that dims the golden orb of day,
And the moon labouring through her changeful way;
Whence rocks the earth, by what vast force the main
Now bursts its barriers, now subsides again;
Why wintry suns in ocean swiftly fade,
Or what delays night's slow-descending shade.
But if chill blood, long lingering in my vein,
From Nature's secret lore my search restrain,

ternal viscera and in their actions manifested an understanding of it in preparing for future events. Now Virgil disdained such supercheries, patching out the superstitions of the time when they were universal, for use at a time when they were employed only to sway the minds oppressed by ignorance and credulity. He concluded that it was the rarefaction and condensation of the atmosphere which agitated the bodies of twittering birds and bellowing cattle,

et laetae pecudes et ovantes gutture corvi.

It was the "Jupiter Uvidus" who rarefied the air and condensed it, so no reverence was lost. When the winds of heaven blew the ethereal disturbance was conveyed to the minds of men, the subtle pneuma gliding past their hearts, and governed the flights of the birds of the air[4] and the tossing heads of the beasts of the field. We are unable still to add much to this except our indifferent skepticism, but we should remember we have as yet hardly lifted a corner of the veil of the ignorance which prevails in modern science as to the atmospheric influences exerted on living beings. We know nothing of the changes in the psychical state by virtue of which the animal does this or that. We put them all down to heat and cold, "dense and rare" and Virgil did as much.

Virgil's pantheism was the pantheism of his day and that it filled the air all around him we can see in his youthful poem, the Culex. The whole theme is the feeling of the gifted boy that the poor gnat which he destroyed at a blow was a possessor like himself of a shred of the soul of the Infinite. It was the sting of the insect which was the interference of God and it saved the sleeping shepherd, in whose name Virgil sings, from the venom of a spotted snake. This philosophy Virgil found in his youth and it dwelt with him through life, but it in no way distinguished him from his contemporaries, however well it fitted in with the beliefs of Dante's time. It is seen in the work of his earlier manhood in the way he speaks in his bucolics[5] of the bees and the phenomena they exhibit as an evidence of the workings of the universal mind. I believe we call it instinct now, though perhaps there has been little left of that term in the recent overturn in biology. We find the mystic theory at the maturity of his marvelous powers in the Aeneid[6] where the hero, visiting his father in Hades, learns from him the nature of creation, how even in the beginning, Anchises says, "heaven and earth and the flowing fields of the sea and the blazing sun, the moon and the Titanian stars are animated by the spirit within them." Unless we keep before us this saturation of the ancient mind with this philosophy, far beyond the point of our own vague thoughts, we will find it difficult to understand how so many, indeed nearly all, clear minds of antiquity adopted vitalistic doctrines as a part of their science. Even Aristotle, deeply analytical as was his mind, saw no skulking, no begging the question in his use of the "entelechy."

However, as we have seen, even Virgil's poetic mind had a touch of practical materialism and he placed the density and the rarefaction of the air in between the cawing of crows and the divine mind. As it was these which explained for him the state of the weather and the fluttering of the birds, so it is the rarity and compactness of the soil which tells the farmer whether the field is adapted to grape growing or wheat culture. The same words—densa and rara—are used for the soil as for the air.[7] But there is something more to be learned from an examination of the soil than this and it is by a method curiously in accord with a part of the modern technique of soil analysis, rudimentary though it is. There is a touch of his wonderful art in its description which I will not attempt to give. A salt and bitter earth is bad for fruits and it is not helped by plowing. To make a test of the condition, put the bad soil carefully ground up into a basket or sieve and through it filter sweet water from the spring. As the drops of water emerge on the wicker work of the primitive filter their quality may be tested by the tongue. The acidity or the alkalinity of the soil is thus betrayed to one of the senses, that of taste, instead of by the visible reactions of the modern test tube. The richness, the "fatness of the soil," betrays itself to the sense of touch as it is exercised between the fingers when it is finely pulverized. Such beginnings then as were possible for scientific endeavor Virgil records and his theory of atmospheric pressure was singularly near the results obtained by the barometer as to the processes of nature which precede atmospheric disturbances more evident then than now to the unaided senses.

JONATHAN WRIGHT

PLEASANTVILLE, NEW YORK

[4] Georgicon I. 417–422.

[5] Georgicon IIII. 219–222.

[6] Aeneis VI. 724 seq.

[7] Georgicon II. 226–228.

TRANSITION ZONES

THE thesis here presented is that the indefinite territory existing between two faunal areas should be considered primarily as a transition zone, not as a unit faunal area or sub-area.

A faunal area may be defined as an area characterized by certain animals and thus differentiated from other faunal areas characterized by other animals. The arctic, temperate and tropic zones are so characterized and may be treated as primary faunal

areas and their subdivisions again as secondary faunal areas. This concept is a very useful one and works out especially prettily in mountainous regions where high altitudes give the same like conditions as high latitudes and are associated with the same forms of life. In America, high latitude conditions and high latitude birds, for instance, follow the mountain ranges towards the equator, a fact that is brought out prettily in a map showing the tongues and islands of high latitude life near the mountain tops and bands of temperate life below on the mountain side.

The first point that the writer desires to make here is that, however interesting it is to plot such latitude-altitude zones in a mountainous country, they do not necessarily constitute sound faunal areas or units in problems of zoogeography. The reason is simple enough, for they are based almost entirely on temperature, whereas precipitation and topography are equally important factors in determining the kinds and dispersal of life. With these three determining factors working variously together or opposed, it is not a theoretical necessity that large faunal areas can be predicated and subdivided in any system that will be a matter of fact rather than a matter of opinion. It so happens, however, that they can be.

Take now the United States and Canada. It would seem to the writer that the primary faunal areas in this region are three; Canadian, Carolinian and Western; Canadian and Carolinian based on latitude, their boundaries modified by altitude; the Western sharply separated from the Carolinian to the east by the precipitation factor and less sharply from the Canadian to the northeast by the topography factor. Canadian and Carolinian areas are uniform with uniform faunas. The Western area, due to its topographic variety and resultant temperature and precipitation variation, is exceedingly varied and may be advantageously divided into minor areas, as has been done.

In the East, the Canadian to the north, and the Carolinian to the south are uniform faunal areas, but between the two lies an irregular transition zone of varying width (as here understood more or less synonymous with the "Transition Zone" of current latitude-altitude zonal divisions of mammals and birds). The ordinary climatic controls seem here to be subordinated to various minor topographic influences which are hard to predicate. For instance, of two related birds of the genus *Vermivora,* near the Atlantic coast, one, *V. chrysoptera,* breeds in broken transition country to the north; the other, *V. pinus,* southerly in the coastal plain edge of the Carolinian; whereas, going to western Pennsylvania, *V. chrysoptera* breeds in typical Carolinian broken country and *V. pinus* north of it in less broken country. This transition zone is not entirely an intermingling of Canadian and Carolinian forms. In birds, for instance, certain forms are peculiarly characteristic of it. Endemic forms in a transition zone, however, do not make it a faunal area. It is, and should be considered as, a transition zone between faunal areas.

A transition zone which has considerably influenced the writer's viewpoint on this problem is one affecting marine, not land, animals. Off the Atlantic coast of our middle states the Continental Shelf extends out some miles with depths increasing gradually. Then, at about 50 fathoms, it rounds off abruptly into the deep sea. As regards fish life, the inshore waters are here the meeting place of two definite shore faunas, a northern North Atlantic, and a southern American coastal faunal area (with species of shore fishes which differ from the shore fishes of Europe or elsewhere). The deep sea beyond the edge of the Continental Shelf harbors fishes of an entirely different sort and should be considered as a deep sea faunal area. The catch brought up by a beam-trawler from 65 fathoms or somewhat more on the slope from the Continental Shelf into the deep may comprise certain species, notably the spined dogfish, and likely *Poronotus,* the sea robin, in late fall, characteristic of the shore area. With them may come the bright red, grotesque *Peristedion* or deep-water sea robin, obviously from the adjacent deep-sea area. There will also be certain species endemic to this narrow strip of sloping bottom, namely, the tilefish, *Zenopsis* (allied to the John Dory of Europe) and *Catulus retifer* (related to the European dogfish). All three are shore derivatives rather than deep-sea derivatives, but, strangely enough, not represented in the faunal areas of shore fishes adjacent. Dory and dogfish represent the southern European shore fauna, and the tilefish perhaps has its nearest shore relatives in the Blanquillos of the Pacific coast. Why are these fish present in this transition zone? One viewpoint only seems to explain it—that between the shore fauna inside and the deep water fauna outside is in some way a favorable locality for foreign species to gain a foothold. With this in mind, we have the following hypothesis concerning transition zones—that they are lines of weakness which representatives of outside faunas may penetrate and where they may establish themselves.

To return to the land faunas of America. Is there any indication of such penetration in the transition zones between the faunal areas postulated? There are certain things which may be so interpreted. It will be noted that the prairie chicken from the west reached the Atlantic coast in a transition latitude and established a race on Martha's Vineyard. Further north or further south it must have penetrated through country more strongly held by the ruffed grouse on the one hand or the bobwhite on the other.

Eastward extension of prairie forms in the latitude of the transition zone south of the Great Lakes is a phenomenon in line with this hypothesis. Also, certain eastern birds cross the prairies and penetrate surprising distances to the northwest in the ill-defined and broken transition zone there existent between the western and Canadian faunal areas, a notable example being the eastern kingbird, which breeds at least in eastern Washington. The prairie area of the Mississippi Valley (as differentiated from the dry plains area west of it) is a transition zone between the east, with sufficient, and the west, with insufficient, rainfall. In the main, its bird fauna is either eastern or western, but it does not lack species almost exclusively confined to it, such as Bell's vireo, a summer resident, or Harris's sparrow, as a transient species.

In conclusion, the writer wishes to point out his concept that between two faunal areas there is normally a transition zone. To consider this also as a faunal area and use it as a unit in zoographical discussions can lead only to complication and confusion. Looked at as what it is, a separate phenomenon, it will repay analysis and study.

J. T. NICHOLS

THE AMERICAN MUSEUM
OF NATURAL HISTORY

THE INTERNATIONAL CRITICAL TABLES

THE Board of Editors of International Critical Tables met in Washington, D. C., for a three-day session beginning on August 16 for the purpose of selecting the cooperating experts who will be invited to assume responsibility for critically compiling the various classes of data to be included in the tables. It is estimated that some three or four hundred cooperating experts will be needed and the selection will be made largely on the basis of recommendations received from the corresponding editors and their advisory committees from the principal countries of the world. Several sessions of the board will be required before the complete list can be made up. Invitations to act in the capacity of cooperating experts will be issued from the editorial office as fast as action is taken by the board and, from the responses thus far received, a full measure of cooperation is expected from the chemists and physicists of the world in making this undertaking a success. In dividing the subject-matter for purposes of assignment to the cooperating experts, the editorial board has endeavored to make each assignment of such a magnitude that it can be reasonably completed in a year's time without proving too great a burden upon any expert and if each one associated with the work will cheerfully accept and carry out his share and responsibility, the combined result of the labors of all who cooperate in the work will be invaluable to science and industry.

The scope of the work is so great and the fields to be covered so varied in character that only through the joint labors of a large number of experts will it be possible to bring the undertaking to a successful conclusion in a reasonable time. The International *Annual* Tables is now in its twelfth year. It has demonstrated the possibility of preparing through international cooperation an annual abstract of the results of the world's researches in quantitative measurement. The purpose of International *Critical* Tables is to take an account of stock of our present quantitative knowledge of material things and to publish in convenient form the result of expert criticism of this knowledge. The practicability of further effective international cooperation on scientific projects will doubtless be judged largely by the degree of success obtained in these efforts.

The International Union of Pure and Applied Chemistry and the International Research Council have given the weight of their authority and influence to International Critical Tables. American industries will supply the necessary funds. It remains only for the scientists of the world to contribute their time, energy and expert knowledge to insure the successful completion of the undertaking. Science itself is international. The preparation of the record of scientific achievement in quantitative measurement should also be international. If the results of scientific research are to be utilized most efficiently, they must first be made easily accessible. To make these results accessible so that they may be utilized to the best advantage is as much the duty of men of science as are the researches which produce them, and the task of rendering these results readily accessible requires the cooperation of the same types of expert knowledge as have been employed in producing them.

As rapidly as appointments of cooperating experts are made and accepted, announcement thereof will be made in the scientific and technical press.

The organization of International Critical Tables is as follows:

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SCIENTIFIC EVENTS

THE PULPWOOD RESOURCES OF CANADA

A ROYAL commission to investigate Canada's pulpwood resources and the advisability of prohibiting the export of this product has been appointed by the Canadian Government. The commission is headed by Joseph Picard, Quebec, a manufacturer and business man, and includes in its personnel two lawyers, one lumberman and one contractor. Instructions have been issued to the commission to inquire into the report upon the forest resources, with particular regard to the extent in each province of woods of various kinds available for the manufacture of pulp. Other directions to the commission follow:

1. To inquire into the quantity of pulp available, owned by the provincial governments and subject under provincial laws and regulations to restrictions requiring the partial or total manufacture of such wood in Canada.

2. To inquire into the quantity of wood so available on lands owned by the Canadian Government and subject under federal laws and regulations to restrictions requiring partial or total manufacture in Canada.

3. The quantity of wood on other lands and the conditions under which such lands are held, whether by ownership or lease, whether by corporations or individuals, whether by citizens of Canada or citizens of other countries.

4. The quantity of pulpwood produced in each province during the past ten years, showing the portion used in Canada and the portion exported.

5. To investigate the question of the restriction of the export of pulpwood from Canada, and any other matter touching upon the production, manufacture or sale of pulpwood essential to a comprehensive consideration of the question of the restriction of export.

The commission is to make recommendations that may be deemed expedient for the better conservation of the supply of pulpwood for present and future use. The pulpwood investigation was promised at the last session of Parliament, when the Government was given power to prohibit the export of pulpwood at that time. The Minister of Finance promised that the Government would not exercise its authority in this respect until after a searching review of the whole situation.

Chemical and Metallurgical Engineering states that the situation brought about by the proposed embargo "has given rise to much speculation as to Canada's ability to continue supplying the United States with pulpwood. It is estimated that Canada has 250,000,000 acres of forest growth of merchantable size, and 600,000,000 forested acres of young timber suitable for pulpwood. It is assumed that the 600,000,000 forested acres of young timber would yield 1,250,000,000 cords of pulpwood. The present consumption is 4,000,000 cords per annum. On that basis the supply would last for over 300 years, without allowing for from two to three per cent. of regrowth; but at that point the authorities differ. It is stoutly maintained by some experts that Canada has not as much pulpwood in sight as is supposed, and that on the basis of consumption during the past twenty years in particular, the resources would be exhausted in 60 years, or reduced to a volume which would mean exceedingly high cost for pulp."

THE FOSSIL FIELD IN MONGOLIA

THE Peking correspondent of the London *Times* writes that the researches of Mr. Roy Chapman Andrews, who for some years has been exploring the less-known regions of China and adjacent territory in the interest of the Natural History Museum of New York, are likely to add considerably to scientific understanding of prehistoric times.

Mr. Andrews concludes that Mongolia is one of the greatest fossil fields in the world, and his discoveries in this respect go far to confirm the theory that Central Asia was the center of the dispersal of the mammalian life of Europe and America. He says that the existence of a land connection between Asia and North America has been unquestionably established.

With reference to the work of the Third Asiatic Expedition under his leadership, now busy in the Gobi Desert at a point about four hundred miles northwest of Peking, Mr. Andrews says:

The first month of the expedition's work is far beyond our hopes. Where we expected only fragments we have discovered an immense deposit of large and small dinosaur bones. It will require many months to exhaust this region, but we have removed two partially complete skeletons and parts of several others. This includes herbivorous dinosaurs 30 feet long of the iguanodon type and smaller carnivorous species. These bones are at least five million years old, but beautifully preserved. They probably are related to European types and, with our former work, indicate that Central Asia is the ancestral home of the dinosaurs, which migrated to Europe and America.

The expedition is now divided into two parts. One is working in the dinosaur beds and the other exploring later geological strata. The second group, camped 24

miles south of the first, is working in eocene deposits, the dawn period of mammalian life. The strata are extraordinarily rich in fossil remains. We have discovered the skull of a giant rhinoceros—like the beast known as the titanothere, which, although it has been buried for three million years, is almost as perfect as though the animal had died a week ago. The titanotheres were previously only known in America. Finding this particular stage in their development shows that they crossed from America by way of a former land bridge to Asia.

We have found, also, remains of a giant dog-like carnivore, as well as many teeth and jaws of an ancestral tapir-like animal. We could spend easily a year's work in these great deposits, but will give them only enough time to get a few of the choicest things.

THE GODMAN AND SALVIN MEMORIAL

A TABLET in memory of Frederick Du Cane Godman, F.R.S., and Osbert Salvin, F.R.S., has been unveiled by Lord Rothschild, chairman of the memorial committee, at the Natural History Museum, South Kensington, and accepted on behalf of the trustees of the British Museum by the Archbishop of Canterbury.

The London *Times* notes that these two distinguished men of science were intimately associated in research and the results of their labors form an important part of the treasures of the Natural History Museum. The friendship between them dated from the fifties of the last century, when they were both undergraduates at Cambridge, and lasted until the death in 1898 of Salvin, who was survived twenty-one years by Godman, the latter dying in 1919, in his eighty-sixth year. In 1876 the two friends conceived the idea of the monumental work entitled *Biologia Centrali-Americana,* which has been described as without doubt the greatest work of the kind ever planned and carried out by private individuals.

As completed, the Biologia consists of sixty-three volumes, of which one forms the introduction, fifty-one are devoted to zoology, five to botany, and six to archeology. The work was edited by Salvin and Godman, and after Salvin's death by Godman alone. The three volumes on the birds and three others on the diurnal lepidoptera were prepared by Godman and Salvin themselves, while the others were written by various specialists. The volumes contain 1,677 plates, of which more than nine hundred are colored, and the total number of species is 50,263, of which 19,263 are described for the first time.

In 1885 Godman and Salvin resolved to present their wonderful neo-tropical collections to the British Museum. Of birds' skins alone over 520,000 were contained in this magnificent donation, which included not only the collections made by Salvin and Godman themselves, chiefly in Guatemala, but many others from various parts of South America, the Mexican collections obtained by Godman himself and his collectors, made in that country in 1887, and the great Henshaw collection of the birds of the United States containing over 13,000 specimens, which was secured by Godman in order to provide a thoroughly authentic series of North American birds for comparison with those of Mexico and Central America.

The commemorative tablet, with portraits in relief of Salvin and Godman, is placed on the wall of the central hall of the museum, near and behind the statue of Darwin.

Lord Rothschild, in presenting the tablet on behalf of the subscribers, explained that the committee had decided that any subscriptions left over after the memorial had been paid for should be devoted to a collecting fellowship. Shortly after that decision Dame Alice Godman and the Misses Godman devoted a further sum of £5,000 to the Godman Exploration Fund, to which others had given further donations.

The Archbishop of Canterbury, in accepting the tablet, expressed the cordial welcome given by the trustees to gifts of that kind. Mr. Godman was one with whom it had been his privilege to sit for years as one of the trustees on the committee of management of museum affairs. Those who shared that privilege knew well how wide was the range of his knowledge and how applicable it was to almost anything that might arise. The Archbishop commended the setting up of memorials of great representatives of science and great benefactors to the museum. In Mr. Godman they had not only one of the donors to whom they owed so much, but also a valued trustee. He wanted to emphasize the importance which seemed to him to attach to taking care that such names, such acts, such memories and such lives should not be forgotten by those who looked at the specimens and collections the museum contained. He believed that in thus recording the services rendered by men such as Mr. Godman and Mr. Salvin they were serving the best interests of the museum.

SIR WILLIAM THISELTON-DYER

THE following letter, printed in *Nature,* has been addressed by British botanists to Sir William Thiselton-Dyer, who celebrated his eightieth birthday on July 28:

The occasion of your eightieth birthday affords us the opportunity of which we gladly avail ourselves, not only of offering you our congratulations upon having attained so venerable an age, but also of assuring you of our continued regard and esteem. In doing so we who sign this letter do but acknowledge our indebtedness to you for the inspiration and guidance which we, both as teachers and researchers, have derived directly or indirectly from your own early work as a professor of botany. We regard that work, and more especially the courses of practical instruction conducted by you at South Kensington

in the years 1875 and 1876, as having inaugurated the renaissance of the study of the structure and functions of plants which had been so brilliantly carried on by British botanists in earlier times. It must, we feel sure, afford you great and justifiable satisfaction to contemplate the marvelous development of such studies in this country during the years that have passed since you quickened them into new life.

The professorial career on which you had embarked so brilliantly was unfortunately, as it may have seemed at the time, brought to a close by your appointment to the assistant directorship of Kew in 1875 and your subsequent appointment as director ten years later. The work that you were enabled to carry out at Kew has been of such national importance that, however much we may regret the loss of the stimulating influence you would undoubtedly have exerted as a professor, we all realize the great and lasting services you have rendered to botany, not only from the purely scientific point of view, but also in relation to the development and encouragement of botanical enterprise throughout the British Empire.

Another notable result of the interest you inspired was the successful launching of the *Annals of Botany*, which has come to be one of the leading botanical periodicals of the world. We do not forget that it was your enthusiasm that turned the scale when the question of "to be or not to be" hung in the balance. The *Annals* is a lasting monument to your courage and prescience.

It would need a lengthy document were we to attempt to set out in detail the value of your many efforts for the promotion of our science, but in conclusion we feel we must refer to the noble work you did in saving the old Chelsea Physic Garden from destruction. Thanks to you, London has now a botanic garden where students and teachers can study the structure and functions of plants and pursue those studies which you did so much to promote.

With our very kind regards and good wishes,
Believe us to be, dear Sir William,
Yours very truly,

D. H. SCOTT	F. KEEBLE
S. H. VINES	A. B. RENDLE
F. O. BOWER	A. SHIPLEY
BALFOUR	H. WAGER
H. T. BROWN	F. F. BLACKMAN
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F. DARWIN	F. W. OLIVER
H. H. DIXON	A. G. TANSLEY
A. C. SEWARD	F. E. WEISS
J. B. FARMER	A. W. HILL

and all the leading botanists in Great Britain and Ireland.

SCIENTIFIC NOTES AND NEWS

THE University of Strasbourg has conferred the title of doctor *honoris causa* on Drs. Simon Flexner and Jacques Loeb, of the Rockefeller Institute for Medical Research; William H. Welch, of the Johns Hopkins University; William Maddock Bayliss and Ernest Henry Starling, of the University College of London; John Newport Langley, of the University of Cambridge; Edward L. Ehlers, of the University of Copenhagen; Jules J. B. Bordet, of the University of Brussels; Edoardo Perroncito, of the University of Turin, and Santiago Ramon y Cajal, of the University of Madrid.

AT the general public meeting of the American Chemical Society on Tuesday, September 11, addresses of welcome will be delivered by C. H. Hall, chairman of the Milwaukee Section; Hon. Daniel Hoan, mayor of Milwaukee; Hon. Emanuel Philipp, president of the Milwaukee Association of Commerce, and President Fox, of Milwaukee University. The general addresses at this meeting will be delivered by Dr. Charles F. Burgess, who will speak on "Marketing chemical discoveries," and Dean R. T. Kendall, of the Medical School, Northwestern University, who will speak on "Bacteria and the chemist."

THE following awards have been made by the Royal College of Physicians, London: The Baly gold medal, given every alternate year for distinction in the science of physiology, to Mr. J. Barcroft; the Bisset-Hawkins medal, bestowed triennially for work in advancing sanitary science or in promoting public health, to Dr. T. M. Legge.

AT the International Surgical Congress recently held in London, Dr. Davide Giordano, Venice, Italy, was elected president to succeed Sir William Macewen. The predecessors in the presidency of these congresses were: Kocher, of Berne; Czerny, of Heidelberg; Championnière, of Paris; Depage, of Brussels, and Keen, of Philadelphia. The next congress will be held in Rome.

WE learn from the *Journal* of the American Medical Association that more than twenty physicians of Ontario were candidates at the recent elections to the Canadian Parliament. The following physicians were the successful candidates: Joseph D. Monteith, Stratford; the Hon. David Jamieson, Durham; Arthur G. Wallis, Algoma; Leeming Carr, East Hamilton; George V. Harcourt, Parry Sound; Forbes E. Godfrey, West York, and John P. Vrooman, Lennox.

THE National Alliance for the Increase of the French Population has awarded the first prize of 50,000 fr. to M. Paul Haury for the best popular pamphlet on the decreasing birth rate in France and the tragic consequences to the nation.

SIR RICHARD GLAZEBROOK has been appointed chairman in charge of exhibits in pure science at the British Empire Exhibition to be held next year in London.

PROFESSOR A. SMITHELLS has been appointed director of the Salters' Institute of Industrial Chemistry, London.

CLARKE E. DAVIS, chief chemist of the National Biscuit Company, and vice-chairman of the New York Section of the American Chemical Society, will succeed Dr. C. A. Browne as chairman of the section when the latter assumes his new duties as chief of the Bureau of Chemistry of the Department of Agriculture.

DR. WALTER G. CAMPBELL, who has been acting chief of the Bureau of Chemistry, has been appointed director of regulatory work of the Department of Agriculture.

R. L. CORBY, director of the research laboratories of the Fleischmann Yeast Company, will open the symposium on "Bread Production," September 11, at the twenty-sixth annual convention of the American Bakers' Association, which will be held at French Lick, Ind., the week of September 9.

WILLIAM HARPER DEAN, formerly of the U. S. Department of Agriculture, has been appointed manager of a Bureau of Agriculture recently established by the Chamber of Commerce of the United States.

DR. ELLIOTT S. ROBINSON has been appointed as assistant director of the Division of Biologic Laboratories of the Massachusetts State Department of Public Health to succeed Dr. Robert N. Nye.

DR. FRANK L. KELLEY, lecturer in preventive medicine and hygiene, and director of the state hygiene laboratory at the University of California, has been appointed health officer of Berkeley to succeed Dr. Ernest H. Pape.

ON August 10, a complimentary dinner was given in San Francisco by the California Academy of Sciences and biologists of the San Francisco Bay region to Dr. and Mrs. Robert P. Bigelow, of the Massachusetts Institute of Technology. Resident naturalists of the Bay region to the number of twenty were in attendance.

DR. H. A. GLEASON, assistant director of the New York Botanical Garden, is spending two months at the Biological Station of the University of Michigan, Douglas Lake, Michigan, continuing researches on the application of statistical methods to the study of plant association.

DR. A. B. STOUT, director of the laboratories of the New York Botanical Garden, has returned to the garden after nine months at Pomona College, Claremont, California, where he was occupied with a study of fertility, sterility and pollination in the date palm, the avocado and the citrus fruits.

PROFESSOR HERMANN THOMS, dean of the Pharmaceutical Institute of the University of Berlin, has been visiting the United States on his way to lecture in Japan.

J. H. CROSSLEY, of the Metropolitan-Vickers Electrical Company, Manchester, England, was lately in the United States studying industrial electric heating developments for the purpose of promoting the application of electricity in England.

DR. GEORGE BIRD GRINNELL, in company with Christopher G. La Farge, New York architect; Col. Henry Hall, a Washington writer, and Barrington Moore, secretary of the National Parks Committee, began on August 21 a survey of the country west of the Big Horn Mountains as a possible national park site.

THE Department of Commerce has announced the personnel of the Caribbean rubber investigating party which sailed from the United States for Panama on July 25 to investigate the rubber plantation possibilities of Panama, Colombia, Venezuela, the Central American countries and Mexico. John C. Treadwell, of the Continental Rubber Company of New York, will be in charge of the party. Hugh H. Bennett, of the Bureau of Soils, Department of Agriculture, will accompany Mr. Treadwell as assistant.

DR. C. U. ARIENS KAPPERS, Amsterdam, director of the Netherlands central institute for research on the brain, has been appointed by the Rockefeller Foundation to give a course of lectures on the anatomy of the brain at the Peking Medical School, and will leave for China in August.

ON the topmost ledge of the rocks on Slide Mountain, the highest peak in the Catskills, the Winnisook Club, of Poughkeepsie, N. Y., on August 18 dedicated a tablet to the memory of the late John Burroughs. The tablet is affixed to the ledge under which Mr. Burroughs passed the night several times as he relates in "The Heart of the Southern Catskills."

AN international subscription has been opened to secure funds for the erection of a monument at Roscoff in memory of Dr. Yves Delage, under the auspices of M. Léon Bérard, minister of public instruction; M. Paul Appell, rector of the University of Paris; M. Picard and M. Lacroix, secretaries of the Academy of Sciences, and other men of science. Delage was a professor at the Sorbonne, and director of the biological station at Roscoff.

FETES in honor of Fabre, the famous French entomologist, began on August 6 at Millau (Aveyron). A monument, the work of the sculptor Malet, representing Fabre, a magnifying glass in his hand, examining

an insect, was unveiled. It was actually at St. Léons that Fabre was born, but St. Léons is a little village of a few hundred inhabitants, and it was thought desirable to erect the statue in the neighboring town of Millau. Fabre is chiefly associated with Sérignan, near Orange, for it was here in his garden that he pursued his entomological studies.

ACCORDING to the *Journal* of the American Medical Association the Paris branch of the Franco-Mexican Association has presented to the Pasteur Institute a replica of the medallion likeness of Pasteur that was hung on the walls of the department of medicine of the University of Mexico on the occasion of the centennial celebration. The bestowal of this work of art took place in the crypt of the institute, at the entrance to the tomb of Pasteur, the presentation speech being given by M. Honnorat, former minister and honorary president of the French section of the Franco-Mexican Association. Dr. Roux, director of the Pasteur Institute, expressed his thanks to the association for the gift and the honor accorded to the memory of Pasteur.

THE German societies for physics, the applied physical sciences and Roentgen rays held recently a joint meeting at Berlin in the large hall of the university in memory of Roentgen. The president of the republic and scientific men from all over the country spoke on the importance of Roentgen's discovery to different branches of science.

A COMMEMORATIVE tablet has been placed by the London County Council on the former residence of James Clerk Maxwell, physicist (1831–1879).

THE Hancock Life Insurance Company, Boston, has given $20,000 to the Harvard Cancer Commission, of which sum a fourth is to purchase diagnostic apparatus; the remainder is for the permanent fund. The insurance company previously gave $30,000 toward the building of the Huntington Hospital, which is devoted to cancer cases.

UNIVERSITY AND EDUCATIONAL NOTES

THE legislature has made special appropriations to the Michigan College and Station for the ensuing biennium of $1,070,000. This is in addition to the receipts from the mill tax, which aggregate about $1,000,000 and are used entirely for operating expenses. The principal items in the special appropriation are $400,000 for a horticultural building and greenhouse, $300,000 for extension work, $150,000 for a power house, $50,000 for a college hospital, $70,000 for research, and $100,000 for miscellaneous buildings.

PROFESSOR A. H. PATTERSON, head of the department of physics and dean of the School of Applied Science in the University of North Carolina, will spend the year 1923–24 in study at Harvard University, on leave of absence. His place will be filled during his absence by Dr. Paul H. Dike, who has been in charge of physics at Robert College, Constantinople, for some years past, though Dr. Otto Stuhlman, Jr., will serve as head of the department, while the duties of the deanship will be assumed by Dr. J. M. Bell, of the department of chemistry.

AT the University of Missouri, Eli Stuart Haynes, of Beloit College, has been elected professor of astronomy; Dr W. B. Robertson, of the University of Kansas, assistant professor of zoology, and Dr. H. C. Howard, Jr., assistant professor of analytical chemistry.

DR. A. RICHARD BLISS, Jr., professor of pharmacology in the Emory University School of Medicine, Atlanta, has resigned to accept the professorship of physiology and pharmacology at the University of Tennessee. Dr. Monroe F. Brown, assistant professor in the department, also goes to Tennessee.

MR. J. BASIL BUXTON, now on the staff of the Medical Research Council, London, has been elected into the newly established professorship of animal pathology in the University of Cambridge.

M. Goss has been elected to a newly established chair of mathematics at the University of Grenoble.

DISCUSSION AND CORRESPONDENCE

THE MARINE LABORATORY AT TORTUGAS

DURING the past year a number of papers appeared in SCIENCE and elsewhere[1] which discussed the desirability of continuing the Department of Marine Biology of the Carnegie Institution of Washington and its most important single activity, the laboratory at Tortugas. Since the officers of the Carnegie Institution have not yet announced what their policy toward the Department of Marine Biology is to be, it may be presumed that the question of continuing this department is still under consideration. This department, having been created in the interest of biologists working on tropical organisms, will probably be continued only if it is evident that a sufficient number of biologists are still actively interested in this kind of work.

1 Davenport, SCIENCE, Vol. 56, p. 134.
Schaeffer, SCIENCE, Vol. 56, p. 468.
Crozier, SCIENCE, Vol. 56, p. 751.
Crozier, SCIENCE, Vol. 57, p. 498.
Fisher, SCIENCE, Vol. 57, p. 233.
Allen, SCIENCE, Vol. 57, p. 499.
Coe, *Amer. Jour. Sci.*, Ser. V, Vol. 4, p. 173.
Potts, *Nature*, Vol. 110, p. 224.

The papers to which reference was made above are unanimous in agreeing that the Department of Marine Biology should be continued, but there is divergence of opinion as to the desirability of continued operation of the laboratory at Tortugas, the alternative suggestion being the establishment of a *permanent* laboratory of the type of Wood's Hole, Plymouth or Naples and located somewhere in the tropics or the subtropics or in Bermuda or southern California. It is with reference to the latter suggestion that I wish to contribute the following observations to the discussion.

As a general proposition, biologists would probably be almost unanimous in welcoming the establishment of a permanent laboratory in another faunal and floral region than the one Wood's Hole now draws upon; there is no doubt that its facilities could and would be used to advantage. But since it seems only a remote possibility at best that such a station will be established at present because of the great expense involved, it seems to me to be far more in the interest of biology to urge instead the retention of a station already in effective operation. It may be added that because of the more or less temporary nature of the laboratory at Tortugas, it could be moved to another locality without great expense, and its transformation into a permanent station at Panama or Jamaica or any of the localities named above, could be effected at any time in the future at no greater expense than would attach to such change now. It may be presumed that as soon as a considerable body of biologists strongly feel the necessity of a permanent station in our southern waters the Carnegie Institution or some other agency of research will take the matter under serious consideration.

In weighing the desirability of continuing the operation of the Tortugas station the following seem to me to be among its outstanding qualities and should receive careful consideration:

1. For American biologists, Tortugas is the best equipped and most accessible tropical marine station.

2. It has been in effective operation for eighteen years and the large amount of published results emanating from it are generally admitted to be of high order.

3. The work carried on there could not for the most part have been done satisfactorily at any other station. It does not compete with but complements the work of other stations.

4. There is evident demand for a station like Tortugas. During the past eighteen years 68 different investigators studied there, each investigator spending on the average three seasons at the laboratory.

5. The living and working conditions are entirely satisfactory.

This point needs a word of explanation. In the earlier years of the laboratory the living conditions were undoubtedly "trying" to a few of the investigators. In recent years, however, a new laboratory has been built and the old one remodeled and the cuisine has been greatly improved, so that the living and working conditions are now in fact considered almost ideal by most of the investigators. One can work ten hours a day every day through the entire season of eight or ten weeks and remain in perfect physical condition. It is not unusual indeed for one to gain in weight while working at this rate.

Altogether the Tortugas laboratory seems too effective an instrumentality for furthering biological science to allow it to lapse with nothing definite in view to take its place.

A. A. SCHAEFFER

HISTORICAL NOTE ON THE PROBLEM OF LIGHT DEFLECTION IN THE SUN'S GRAVITATIONAL FIELD

A SERIES of articles recently published by Professor T. J. J. See, U. S. Navy,[1] gives a quite incorrect impression of the relation of J. Soldner's and of Einstein's work in connection with the deflection of light in the sun's gravitational field. It therefore seems desirable to make a short statement of the history of this problem.

In 1801 Soldner[2] calculated the deflection of light according to (1) The corpuscular theory of light (light consisting of material particles which are subject to gravitation), and (2) Newton's law of gravitation. The problem was simply that of determining the hyperbolic orbit of a small mass traveling with the speed of light under the influence of the gravitation of a celestial body. Considering a ray of light just touching the surface of the attracting body, Soldner worked out the well-known solution of the problem of two bodies. In setting up the differential equations for the motion of the particle he erroneously used for the gravitational force the expression

$$2gr^{-2}$$

where g = acceleration at the surface of the attracting body, and
r = distance from the center of the attracting body (adopting the radius of this body as unit distance).

The factor 2 has no justification and should be omitted.

Designating by ω the angular deflection of light from a star at infinity until it reaches the surface of

[1] San Francisco *Journal*, May 13, 20, 27; 1923.

[2] Bode, "Astronomisches Jahrbuch für das Jahr 1804," Berlin, 1801, p. 161.

the attracting body Soldner derived the formula

$$(1) \qquad \text{tang } \omega = \frac{2g}{v\sqrt{v^2 - 4g}} \quad (v = \text{speed of light})$$

which he applied to the earth and the sun. On account of the mistake mentioned his result for the sun

$$\text{(half deflection) } \omega = 0''.84$$

is twice too large. Correcting Soldner's formula and using modern constants a ray of light just grazing the sun's surface is deviated from infinity to infinity by the angle

$$\alpha = 0''.87$$

if the corpuscular theory of light and Newton's law of gravitation are adopted.

Soldner did not have in mind any test of the theory of light, his sole purpose being to find out whether the gravitational light deflection need be taken into account in astronomical measures of star positions. He was chiefly interested in the effect of the earth's gravitation upon a stellar ray, and he gave the application to the moon and the sun only a short mention at the end of his paper.

Before establishing the generalized theory of relativity, Einstein touched the subject of light deflection in 1908[3] and developed it more fully in 1911.[4] In the second paper Einstein states his principle of the equivalence of a uniform gravitational field with an accelerated system of reference. This principle leads to the necessary conclusion that energy of radiation (light) has inertia or mass, and that this mass must be subject to gravitation. From this conclusion the deflection of light could be calculated by using Soldner's method. Einstein, however, follows an entirely different course. For the time measure of an observer, according to the principle of equivalence, the speed of light in a gravitational field changes from place to place. The path of a light ray is then found by using the Huyghens principle, which leads to the formula

$$(2) \qquad \alpha = \frac{2kM}{c^2\Delta}$$

where α = full deflection of light ray from infinity to infinity
k = constant of gravitation
M = mass of attracting body
Δ = distance of light ray from attracting body
c = speed of light in vacuum.

For the sun Einstein finds $\alpha = 0''.83$, but with more accurate data the value $\alpha = 0''.87$ is obtained. This formula (which is based on the principles (1) Light is subject to gravitation, (2) Gravitation follows Newton's law) is equivalent to Soldner's formula, but is more general.

[3] "Jahrbuch der Radioaktivität und Elektronik," 4, 411, 1908.

[4] "Annalen der Physik," 35, 898, 1911.

In 1916[5] Einstein published his "Generalized Theory of Relativity," in which a new law of gravitation is given, differing from Newton's law by small terms, which, however, become sensible close to the sun, as for example, for the planet Mercury and for light rays passing near the sun. The light deflection required by this generalized theory is twice the amount given by formula (2); Einstein gives 1".7 at the sun's limb, but more accurate calculation gives 1".75. The increase of this value over that in Einstein's 1911 paper is not due to any mistake in calculation in the earlier paper but is an effect of the difference between Einstein's and Newton's law of gravitation, as the 1916 deflection is essentially based on the principles:

(1) Light is subject to gravitation.

(2) Gravitation follows Einstein's law instead of Newton's.

The observations of the 1919 and 1922 eclipses confirm the amount of light deflection predicted by the generalized theory of relativity of 1916 and they should therefore be considered as supporting the two last named principles. There is at present no other theory which satisfactorily explains the observed light deflections as to their numerical values.

The relation of Soldner's work to Einstein's results is characterized by the following points:

(1) It is through a mistake made by him in his work that Soldner obtains an amount of light deflection at the sun's limb which is in agreement with the recent eclipse observations; his theory, correctly developed, can only furnish a basis for half of the observed deflection. Einstein's generalized theory of 1916, on the other hand, necessarily leads to the full deflection observed.

(2) The fundamental assumptions on which Soldner's work is based are equivalent, as far as the present problem is concerned, to those of Einstein's 1911 paper, and Einstein's 1911 results must be and are in agreement with those of Soldner (after correcting Soldner's mistake).

(3) Soldner treats only the case of a light ray grazing the surface of the attracting body; Einstein considers the more general problem of any light ray passing through a gravitational field, and his formula (2) not only gives the light deflection at the sun's edge but also states that for other light rays the deflections are inversely proportional to the distance from the sun's center, a law which is not even touched by Soldner.

(4) The two authors derive their formulae by entirely different methods.

(5) Einstein's result differs from Soldner's formula not only in notation but also in terms of higher

[5] "Annalen der Physik," 49, 769, 1916.

order, and Einstein does *not* repeat Soldner's mistake.

(6) Soldner does not mention the application of this problem for testing the theory of light which is the principal purpose of Einstein.

This comparison sufficiently shows the independence of Einstein's work even if he knew about Soldner's paper, which is not likely, as Soldner's result had fallen into oblivion following the rejection of the corpuscular theory of light on which it is based. Professor See, accusing Einstein of plagiarism, clearly has not read Soldner's original paper and has been misled by a fragmentary reprint[6] of it published in 1921 together with comments by a German physicist, P. Lenard.[7] In these comments (page 603) Lenard transforms Soldner's formula into a notation and form similar to that employed by Einstein. Professor See mistakes Lenard's transformed formula for Soldner's and bases his unfounded accusation upon its similarity to Einstein's result.

ROBERT TRUMPLER

LICK OBSERVATORY

A RECESSIVE BLACK VARIETY OF ROOF RAT

THE pelage color of most wild mammals is characterized by a rhythmical deposition of dark and light pigments in the hair, giving rise to what is termed an agouti pattern. One of the common variations occurring in agouti animals is the disappearance of the bands of yellowish pigment, which results in a totally black coloration, provided no other variations are present simultaneously. It is known that mammals may be black genetically, for one or other of the following reasons: (1) Because they possess a dominant or incompletely dominant extension factor, which extends the dark pigments into the regions ordinarily occupied by the lighter ones only, as in "steel gray" rabbits;[1] (2) because they possess a recessive non-agouti factor which precludes the formation of light pigments in the hair with the dark ones. Most black varieties of domesticated animals belong to the latter class.

The natural color of the black rat, *Mus rattus,* is a uniform black, which has been found to be dominant over the agouti of the closely allied roof rat, *Mus alexandrinus.*[2] This case obviously falls into the first of the above-named categories. Black individuals obtained from a stock received from Mr. H. C. Brooke of Taunton, England, were at first supposed to be specimens of the dominant black derived from *M. rattus.* These blacks were produced in matings between grays and yellows, and it was assumed at first that black would be found to be dominant over gray as in Morgan's experiments. The incorrectness of this assumption was apparent when gray mated to gray produced litters containing black animals; six black rats produced in this way have been recorded. Matings of such black males to wild gray *M. alexandrinus* females have resulted in the production of seventeen offspring, all of which are gray.

This evidence indicates very clearly that we have in this black variety a color factor which is different from the one characterizing the black rat, *Mus rattus;* one which is recessive to gray or agouti, and which is probably the homologue of the factor producing the black variety in the Norway rat, the house mouse, the guinea-pig and the rabbit.

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QUOTATIONS

A "ROSS INSTITUTE"

THE approaching twenty-fifth anniversary of Sir Ronald Ross's epoch-making discovery that malaria is transmitted to man by the mosquito has led a number of influential persons, including leaders of the profession in this country, Mr. H. H. Asquith (ex-prime minister), Dr. Roux, director of the Pasteur Institute, Paris; Dr. R. M. Strong, of Harvard University; Dr. William H. Welch, of Johns Hopkins, and Sir Charles Sherrington, president of the Royal Society, to make an appeal to the public. They point out that the discovery has revolutionized medical science and living conditions throughout the tropics and, among other great things, enabled the Panama Canal to be constructed. It is impossible to exaggerate the services Ross has rendered. He must be ranked among the great investigators whose labors, like those of Pasteur, Lister, Jenner and Golgi, have conferred inestimable and lasting benefits on mankind. All the world has shared in these benefits, but Great Britain, which has vaster tropical areas than have ever been ruled by a single power, has profited most abundantly, and she owes a very special debt of gratitude to the son who has rendered this service. There is in

[6] "Annalen der Physik," 65, 593, 1921.

[7] Lenard, it should be said, recognizes the error in Soldner's work to which attention is called in this paper and gives correctly the value for the deflection to which Soldner's theory leads. It may further be stated that Soldner's result for the light deflection by the Earth $\omega = 0''.001$ is also in error and should be $\omega = 0''.00014$ (in addition to the erroneous factor 2 in the formula a mistake was made in calculating the value of the acceleration for the peculiar units used).

[1] Punnett, R. C., 1912, *Jour. Genet.,* 2, 1915; *ibid.,* 5.

[2] Morgan, T. H., 1909, *Am. Nat.,* 43.

process of organization an institute to be called the "Ronald Ross Clinique for Tropical Diseases and Hygiene," in which it is proposed that laboratory research and clinical investigation shall be combined as closely as possible in accordance with his teaching. There are already in this country two schools of tropical medicine which have done good work, but their activities are in the main educational. It is proposed that the institute shall supplement and not compete with them; that its primary object shall be research, that a clinical establishment shall be maintained in intimate conjunction with the laboratories, and that the master mind of Ross, assisted by other experts, shall have the fullest scope for the initiation and continuation of researches into the still unsolved problems of tropical medicine. There is a Pasteur Institute in Paris; a Kitasato Institute in Japan; a Gorgas Institute in Panama. It is strongly felt that Great Britain should honor one of her greatest investigators by establishing a Ross Institute in London. To initiate this, $250,000 is required. The public is invited to send subscriptions to the honorary treasurer, Lord Willoughby de Broke, 29 Queen Anne Street, London.—*The Journal of the American Medical Association.*

THE DIRECTORSHIP OF THE RECLAMATION SERVICE

SECRETARY WORK might have given a shorter explanation of the recent removal of Arthur Powell Davis, Director of the Reclamation Service, which would have been more convincing. If he had merely said that Mr. Davis was turned out to make room for a practical politician, that would have been enough.

In his long letter addressed to the American Society of Civil Engineers, Secretary Work labors the point that the time when engineering skill and experience were of first importance in the Reclamation Service is past and that the need now is for "a practical business man familiar with conditions peculiar to irrigation in the West" as Director. The facts are that Arthur Powell Davis was for twenty-one years an engineer in the Reclamation Service, that since 1914 he had been director, and during his term of service all the large storage dams of the West were constructed and others begun, and that Gov. D. W. Davis, of Idaho, who succeeds him, has been known only as a grocer and banker who entered state politics.

The charges that big power interests have conspired to bring about the removal of the distinguished engigeer because they are opposed to the Government's policy in reclamation and Arthur Powell Davis's part in it under successive administrations Secretary Work passes over in silence. His answer to the engineers is lame and evasive. To confess the truth would be to admit the unworthiness of his own motives in removing from office Arthur Powell Davis to make room for an Idaho politician.—*The New York World.*

SPECIAL ARTICLES

THE VIBRATIONAL ISOTOPE EFFECT IN THE BAND SPECTRUM OF BORON NITRIDE

THE quantum theory of band spectra[1] indicates that there should be quite appreciable differences between the spectra of isotopic molecules. This is essentially because the spectroscopic frequencies, or, rather, such portions of them as are due to changes in molecular vibrational energy, should be proportional to actual molecular vibration frequencies. The expected isotope effect has already been found[2] in one of the *infra-red absorption* bands of hydrogen chloride; here the absorbed energy is nearly all vibrational.[3] A displacement of 0.055 A.U. has also been found in a comparison of certain lines in the *visible emission* bands of two samples of lead of different atomic weight. Here the emitted radiant energy is partly vibrational, partly electronic in origin.[4]

A much more favorable case than the two foregoing is to be found in boron nitride. Here the vibration frequency should be 2.76 per cent. greater for the lighter isotope $B_{10}N$ than for the heavier, $B_{11}N$, as compared with 0.08 per cent. for HCl and perhaps 0.04 per cent. for lead. The ratio of abundance, 1:5 from the atomic weight 10.83 (Baxter & Scott), is of course somewhat unfavorable. Jevons[5] has measured the heads of two systems of bands which he has satisfactorily shown to be due to boron nitride. In addition to the main "α" and "β" systems, he found certain less developed "subsidiary systems," β_1 and β_2, related to the β system, as well as some extra bands not fitting any system.

Theory predicts that for the band due to the passage of a vibrationless, but electronically excited molecule, to an electronically less excited, and still vibrationless, state, there should be *no isotope effect*

[1] See, for example, Sommerfeld, "Atombau und Spektrallinien," 3rd Ed., Chap. VI.

[2] Loomis, *Astrophys. Journal*, 52, 248 (1920); Kratzer, *Zeit. für Physik.*, 3, 460 (1920).

[3] There is also a change in molecular rotational energy involved, with a corresponding isotope effect. This is, however, usually a minor factor, and will not be considered in the following discussion.

[4] Grebe and Konen, *Phys. Zeit.*, 22, 546 (1921). The emitting molecule is probably that of some lead compound.—The effect should not be confused with those observed in the *line* spectra of lead isotopes.

[5] W. Jevons, *Roy. Soc. Proc.* A, 91, 120 (1915).

except the very small electronic effect corresponding to that in line spectra.[3] This band may be designated (0, 0), since it corresponds to the change $(n' = 0) \rightarrow (n = 0)$, n′ and n respectively denoting the *initial* and *final* number of vibrational quanta possessed by the molecule. The band (0, 0) is usually one of the more intense members of a band system. On the high frequency side of (0, 0) lie bands for which $n' > n$, or strictly, for which $W_{n'} > W_n$, W denoting vibrational energy. Here the electronic energy emission is supplemented by a contribution from the vibrational energy; the reverse is the case for the bands on the low-frequency side, where $W_{n'} < W_n$. Going from (0, 0) toward either shorter or longer wave-lengths in the band system, there should be a progressively increasing displacement between the bands of two isotopes, the frequencies all being *higher* on the *high*-frequency side for the *lighter* isotope, and *lower* on the *low*-frequency side. The reason for this is that the intervals between successive bands are approximately proportional to the molecular vibrational frequencies, so that the bands of the lighter isotope are on a somewhat *more extended scale* than those of the heavier.

In order to apply the theory to the boron nitride bands, it is first necessary to determine the proper values of n and n′ for each band. This can be done without great difficulty with the help of certain criteria applied by Heurlinger to the cyanogen and nitrogen bands. The following equation then gives, in wave-number units (*in vacuo*), by substitution of suitable values of n and n′, the positions of all the 50 heads of the β system

$$\nu = 42885 + 1268.5n' - 10.20n'^2 - 1873n + 11.85n^2.$$

The (0, 0) band lies at $\nu = 42885$ ($\lambda = 2331$ A.U. (in air)); the values of n run from 0 to 10, those of n′ from 0 to 5.[6]

On examining Jevons's data on the position of the β_1 and β_2 systems, it is found that the β_1 bands all lie at lower frequencies than the (0, 0)β band, and the β_2 bands all at higher frequencies. Furthermore, the β_1 band nearest β(0, 0) lies *very near* β(0, 2), on the *low*-frequency side; and the β_2 band nearest β(0,0) lies *very near* β(1, 0), on the *high*-frequency side. Going toward lower and higher frequencies, respectively, the β_1 and β_2 bands become gradually more and more separated from the corresponding β bands. Moreover, each β_1 or β_2 band is *weaker* than the corresponding β band. All this is exactly what would be expected if the β_1 and β_2 bands belong to the lighter isotope $B_{10}N$. This idea is very greatly strengthened by a comparison of the frequency intervals between neighboring β bands (*e.g.*, the bands (1, 3) and (1, 4), or (1, 4) and (1, 5)) with the intervals between corresponding β_1 or β_2 bands. The theory predicts that these intervals should be approximately proportional to the molecular vibration frequencies, and should therefore be greater for $B_{10}N$ than for $B_{11}N$ approximately in the ratio 1.0276. Making the comparison above suggested for every possible pair of β_1 or β_2 bands with the corresponding pair of β bands, an average value of 1.029 is actually obtained for the ratio. In view of the inexactness of the theoretical prediction,[7] the agreement is very good.

The explanation of the apparent gap between the β_1 and β_2 systems is obviously that the bands of the two isotopes lie very near together in this region. There remain a number of bands which should belong in the β_1 system, but which appear to be missing. The positions of these bands can be calculated by means of the following empirical equation which holds for both the β_1 and the β_2 bands:

$$\nu = 42871 + 1306.5n' - 10.50n'^2 - 1925n + 12.188n^2$$

It is then found that the head of every missing $B_{10}N$ band, with three exceptions, should lie just inside the head of a more intense $B_{11}N$ band, so as to be completely masked by the latter.[8] The three remaining bands are accounted for by three bands observed, but not correlated, by Jevons. A $B_{10}N$ band corresponding to *every* observed $B_{11}N$ band of the β system is thus either observed or accounted for.[9]

The maximum displacements between corresponding bands for the two isotopes are of notable magnitude, *viz.*, 4.5 A.U. toward shorter wave-lengths at λ 2145 (band (3, 0)), and 34.1 A.U. toward the red at λ 3256 (band (3, 9)).

The evidence given above as to the presence of a corresponding set of bands for each of the two isotopes of boron nitride leaves little room for doubt, especially in view of the fact that the absence of such bands would seem to involve the overthrow of the present theory of band spectra. There are, however, certain apparent minor discrepancies and gaps in the data, which it is hoped to remove by means of new

[6] A corresponding equation has also been determined for the α system, but as the present data on the isotope effect are much more fragmentary than for the β system, the α system will not be discussed here.

[7] This is due to the fact that the measurements refer to band heads. This introduces a variable rotational isotope effect whose magnitude it is not possible to calculate exactly with the data at hand, but which should, qualitatively, increase the ratio above 1.0276, in agreement with observation.

[8] In most cases the $B_{11}N$ band does not correspond to the same values of n and n′ as the $B_{10}N$ band which it masks.

[9] Note the close approach for the calculated position of the (0, 0) band to that for $B_{11}N$. Discussion of the significance of the remaining difference (presumably electronic isotope effect) will be postponed.